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Beneficial use practice of e-wastes in Republic of Korea

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Abstract

The EPR system, Eco-Assurance System, and the Allbaro system were examined as the regulation of E-wastes in this study. And beneficial use practice of E-wastes in Korea was introduced to improve recycling activities including collection system and recovery center with facilities. In order to improve the recycling of waste in Korea (Republic of), the act on the promotion of saving and recycling of resources was activated in 1992. Under the act, waste charges and waste deposit fee system were operated for several products from industries to promote recycling measurement. Due to the abolition of waste deposit system in 2002, extended producer responsibility (EPR) system was introduced in 20003 by the amendment of recycling law. Since early 2004, the Ministry of Environment of Korea has carried out a feasibility study to introduce an "Eco-Assurance System (The ECOAS)" which would restrict the use of hazardous substances in electrical and electronic equipment and promote recycling of E-wastes by applying a systemic management for life cycle analysis from cradle to grave. On January 2008, the Eco-Assurance Committee System in Korea has been implemented under the Act on the Resource Circulation of Electrical and Electronic Equipment and Vehicles for resource circulation and environmental conservation in a joint legislation by the Ministry of Environment, the Ministry of Knowledge & Economy, and the Ministry of Land, Transport and Maritime Affairs. According to the ECOAS in Korea, 5 product groups and 27 items of WEEE including refrigerator, personal computer, electric oven, audio, and mobile phone are controlled to intensify the recycling capacity in electronic industries.Beneficial use practice of recycling E-Waste in Korea were examined to improve recycling activities including collection system, recovery center with facilities by the information of E-Waste generation and recycling, policy and regulations of E-Waste. Even though total generation of E-wastes was almost constant recently, the generation trend of TV, refrigerator and washing machine was very increased because those products was used in household more than 2 times for past 10 years. Also, recycling rates of those E-wastes will be increased because recycling technologies have been improved and those E-wastes were readily decomposed by heavy parts.

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Keywords: E-waste, recycling, Eco-Assurance system, Extended producer responsibility;

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1. Introduction

During several decades, Korean industries were significantly developed with improving high technologies to produce electrical and electronic equipment. However, Korean industries always have been suffered by high dependency of foreign energy and resources. Hence, it should be solve those difficulties with high recovery efficiency for energy and resources from recycling of E-wastes.

In Korea, the act on the promotion of saving and recycling of resources was activated in 1992. Under the act with discharge fee and deposit system on waste applying to recyclable products from industries to promote waste recycling. Extended producer responsibility (EPR) system was introduced in January 2003 by the abolition of deposit system on waste in 2002.

EPR system in Korea has been activated under the Act on the Promotion of Resources Saving and Recycling on packaging materials such as metal cans, glass bottles, PET bottles, and plastics, and household appliance products such as TVs, refrigerators, washing machines, air conditioners, personal computers, hi-fi systems, fax machine or mobile phones. Under the Act, the obligation rate of recycling wastes in EPR system has been levied on the association of producers and importers of those products. According to EPR system, the association of producer or the importer should be satisfied the obligation rate of recycling wastes which was decided by agreeing between the government and the association of producer and importer. If the association of producer or the importer does not satisfy the obligation rate of recycling wastes, the producer or the importer should pay the recycling charges with fine by the regulation of EPR system. In Korea, 25 waste items have been controlled by EPR system including 10 items of E-wastes.

By affecting the directives on waste electronic and electric equipment (WEEE) and Restriction of Hazardous Substances, Restriction of the use of Hazardous Substances in EEE (RoHS) in EU, the Ministry of Environment in Korea has studied to phase in the new system for an "Eco-Assurance System (ECOAS)" which should restrict the use of hazardous substances in electrical and electronic equipments and promote recycling of E-wastes by applying a systemic management for life cycle analysis from cradle to grave since 2004[1]. The ECOAS in Korea has been activated under the Act on the Resource Circulation of Electrical and Electronic Equipment and Vehicles for resource circulation and environmental conservation in a joint legislation by the Ministry of Environment, the Ministry of Knowledge & Economy, and the Ministry of Land, Transport and Maritime Affairs in 2008. Due to the ECOAS in Korea, E-wastes had been separated from EPR system to strengthen the recycling facilities in electronic industries. The ECOAS in Korea were extended from 10 items of E-wastes in 2008 to 5 product groups and 27 items of E-waste including household small appliances such as electric fan, electric heater, iron, and air purifier, etc. in 2013.

It was examined the generation and recycling of E-wastes, and policy and regulations of E-Waste in Korea. The recycling stream of E-waste was also evaluated. And beneficial use practice of E-waste in Korea was introduced to show recycling efforts including collection program, recovery facilities, and recycling network. Finally it was discussed about the improvement methods for recovery materials from E-waste describing the integrated collection system.

2. The generation and recycling of E-wastes

In Korea, information technology was significantly improved to produce electrical home appliances(EHAs) such as smart TVs, refrigerators, washing machines, mobile phone, and personal computers. And the generation of E-wastes has been increased with increasing the production of EHAs. Also, the recycling of E-waste was concerned to recovery several resources with collecting program.

The generation of E-wastes was slightly increased from 2003 to 2007 and was not increased very much after 2009 as shown in Table 1[2]. Since electric and electronic products were consumed by the effect of economic growth, the stagnation of generation of E-wastes from 2009 was mainly affected by the economic depression in Korea. The generation amount of E-wastes can be represented by national statistics of the production. However, it was very difficult to identify the generation amount of E-wastes because the lifetime of electronic and electric equipment was very long and unauthorized private sector as hidden flow collected E-wastes without any information. The recycling amount and recycling rate of E-waste were increased from 58,000 ton and 12% in 2003 to 158,000 ton and 27% in

2013, respectively. But, the recycling amount of E-wastes by hidden flow was not accounted because there is no data available. According to the association of central junk shop in Korea, the number of junk shops related to hidden flow of E-wastes may be more than 12,000.

Table 1. Generation and recycling amounts of E-wastes (Unit: k ton)

Year	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13
Generation amount	504	596	596	659	662	713	592	641	634	623	595
Recycled amounts	58	66	80	93	107	113	118	133	126	-	158
Recycling rate (%)	12	11	13	14	16	16	20	21	20	-	27

*Source: 2014 International Symposium on Recycling of Valuable Resources

In 2013, the recycling stream of E-wastes by EPR system can be shown in Fig. 1[2]. In the recycling stream of E-waste, it can be collected by several agencies such as producer, local government, collection and transportation, and recycling company. According to EPR system, mutual aid association should try to satisfy the obligation target of recycling E-wastes in order not to pay the fine. Through the recycling stream, the collection portion was about 60% in producer and about 30% in recycling company.

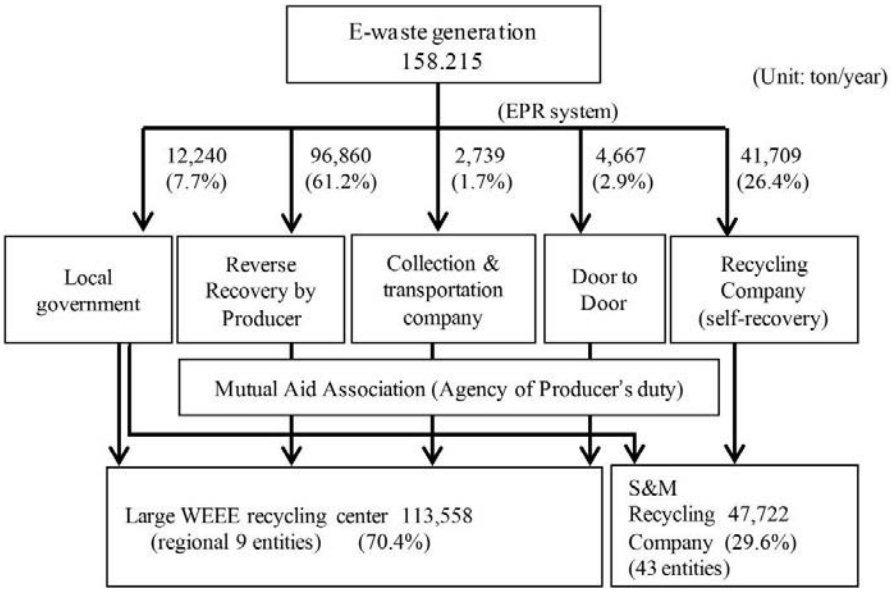

Fig. 1. The recycling stream of E-waste in EPR system (2013)

3. The regulations of E-waste in Korea

3.1. Extended Producer Responsibility (EPR) System

Extended Producer Responsibility (EPR) system in Korea was introduced to replace recycling deposit system on producers and distributors. In order to promote the recycling of E-wastes by the manufacturer and the distributor, EPR system imposed obligation target of recycling on the manufacturer and the distributor that should meet the target of recycling. If the target of recycling is not satisfied with, a fine that is greater than the proper recycling cost shall be imposed on the manufacturer and the distributor.

EPR scheme and target items in Korea can be shown in Table 2 and the total items of EPR were currently increased to 15[3]. Since 2008, wastes of electric and electronic products among EPR items have become subject to

Eco-Assurance System under the Act on the Recycling of Electrical and Electronic Equipment to enhance recycling rate of E-wastes and to control the restrictions on the use of hazardous substances[4].

Major achievements of EPR system from the introduction of the EPR system in 2003 can be described by the increasing waste resources. The obligation rate for EPR products has been continuously increased even though the actual recycling amount and rate were not met to the obligation rate. With respect to batteries, the obligation rate of lithium batteries was increased from 49% in 2008 to 65% in 2014[5]. The obligation rate of dry cell and hybrid batteries was relatively low and almost constant from 2008 to 2014. For fluorescent bulbs, the obligation rate was gradually increased from 23.1% in 2008 to 35.5% in 2014. For E-wastes, the obligation target of recycling was used by recycling rate of percent until 2013 but it was changed to recycling amount per capita from 2014 because recycling of E-wastes will be improved. In 2014, the obligation target of E-wastes recycling was 3.9kg per capita regardless the type of E-wastes[6].

Table 2 EPR scheme and target items

EPR scheme	Legal basis	Target item	
Take-back with recycling targets	Act on the Pro	Package (4)	Packages(metal can, glass bottle, carton pack, synthetic resin packaging material) that are used to pack food and beverages, agricultural products, marine products, livestock products, cleansers, medicines and cosmetics, etc.
		Product (11)	Tire, Fluorescent lamp, Batteries(Mercury, Silver oxide, Lithium, Nickel-cadmium, Manganese, Nickel-hydrogen), Lubricant, Styrofoam float
	Act on Resource Recirculation of Electrical and Electronic waste and End of Life Vehicles	Product(27)	Television, Refrigerator, Washing machine, Air conditioner, Computer, Audio, Mobile phone, Copier, Fax machine, Printer, Automatic dispenser, Electric water purifier, Electric oven, Microwave, Bidet, Air purifier, Electric stove, Electric cooker, Water softener, Humidifier, Iron, Fan, Blender, Vacuum machine, Video cassette Recorder.

3.2. The Allbaro System

The new tracking system, called as the Allbaro System, was introduced by using an electronic information system that computerized the comprehensive waste stream processes from cradle to grave on the computer[7]. The system was developed in 2001, and has been used to track the waste stream processes for industries to produce hazardous wastes. Since 2002, the industries were expanded to waste generator, collection, transportation and final disposal. The Allbaro system can monitor effectively the waste stream processes in a transparent way to prevent illegal recycling and disposal.

The Allbaro system has applied to industries that produced hazardous or general waste until 2004, but the system applied to producers of construction waste since 2005. In 2006, most of waste stream processes from industries and hospitals were monitored to be controlled properly. From 2008, an electronic document system was applied to monitor waste generation, transport, and final disposal. Since 2011, the Allbaro system was applied to all industry wastes generated from industries and had become a user-friendly system with an intensified monitoring system.

In Allbaro system, the portal system for waste export and waste import was established to control transboundary movement of wastes related to Basel Convention. For transboundary movement of wastes, 86 waste items should be received the permission by the Minister of Environment in consultation with the Minister of Trade, Industry and Energy and 25 waste items were notified by exporter or importer to the Minister of the Environment. The portal system has been managed environmental problems caused by wastes of import and export and international conflict by the regulation of permission and notifying system.

3.3. The Eco-Assurance System (ECOAS)

The Eco-Assurance System is aimed to minimize environmental loads through systematic management of entire life cycle of electrical products, electronic devices and vehicles, in order to reduce wastes generation and promote recycling activities.

The ECOAS can be classified by the preventive regulation and follow-up management regulation. In the preventive regulation, the contents are designed to obey the content level of hazardous substances in the products, to satisfy the obligation target of recycling, to improve the materials and structures for recycling, and to exchange recycling information. In the follow-up management regulation, the contents are designed for manufactures and importers to deal with the obligation target of recycling, to satisfy the recycling methods properly, to submit the management sheet of recycling. The ECOAS tried to encourage the recycling with systematic management of E-waste and vehicle products using by life cycle approach.

Main purpose of the ECOAS is collecting waste items as much as possible from producers and 232 local authorities in nationwide. Under the Act on the Recycling of Electrical and Electronic Equipment and Vehicles 2008, the life cycle approach will be applied to promote recycling, save resources, and protect the environment in ECOAS. Also, it can make recycling easier by considering the recycling of waste at the design stage of electronics and automobiles and restricting the use of hazardous substances in the those products.

The ECOAS was expected that hazardous substances in electric and electronic products should be eliminated and recycling facilities are improved. In addition, it may be estimated that the installation of recycling facilities of E-waste would be increased to expand recycling market and boosted the development of recycling technology to recovery precious metals and rare earth metals from E-wastes. With the introduction of ECOAS, the recycling rate of E-wastes was increased gradually with reducing hazardous substances.

4. Beneficial use practice of E-waste

4.1. Beneficial use practice of collection system

Most of E-wastes involved valuable and recyclable resources for each material and also contained hazardous substances such as heavy metals. Hence, it was very important to collect E-wastes efficiently without any environmental pollution to human health.

In Korea, E-waste has been mainly collected by 3 ways such as local government, producers or distributor, and recycling company with self-recovery as shown in Fig 2. Even though there are approximately 3,300 distribution agencies of electric and electronic producers in national wide, about 10% of E-wastes were collected by producers or distributors with the reverse route system in the case of purchasing new products. More than 60% of E-wastes were discharged to 232 local governments by a volume based rate system with sticker which has been applied to household wastes. In Eco-Assurance System, the responsibilities for producer or distributor will be enhanced to collect E-wastes including EHAs. Since most local governments only have the collection system of E-waste without recycling facilities, the cooperation systems was established between producers and local governments to recycle E-wastes efficiently. According to ECOAS, collection centers related to recycling centers collect and transfer EHAs by a happy call system that producers or distributors visited at home by customer call without any collection fee because EHAs were heavy to take out from home to collection center without moving equipments.

The establishment of network system for collecting E-wastes with several collection agencies shall be promoted to collect E-wastes efficiently. In order to improve recycling rate of E-wastes, the network system for collecting should be built for adjoining producers, recycling companies, and local governments to exchange collecting E-wastes information. In the network system, the information of listed E-wastes in each collecting agency shall be shared with each other, and mutual aid associations shall be responsible for installation of collectors, and collection and transportation shall be performed by recycling centers.

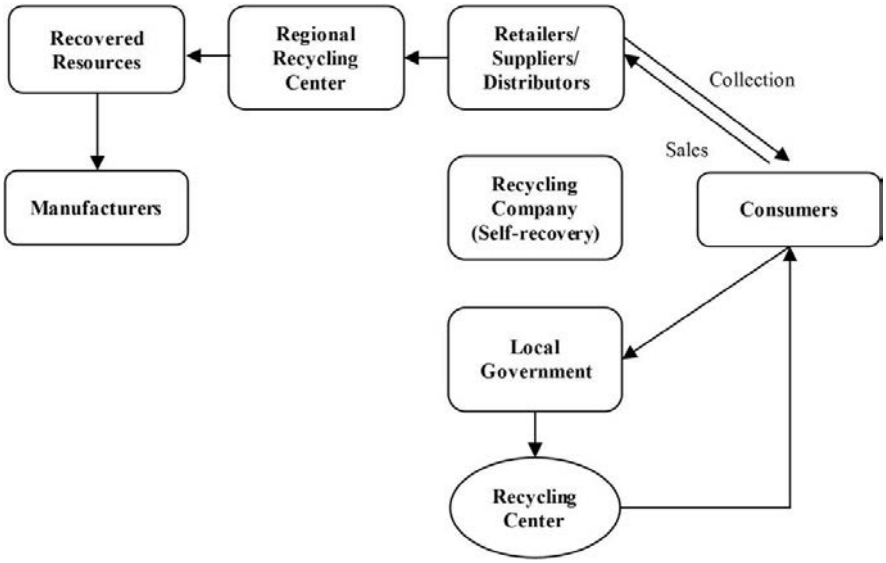

Fig. 2. Collection system of E-wastes in Korea

The beneficial use practice of E-waste was carried out by Samsung Electronics Company from 2008. The amount of E-waste collected in 2012 was more than 92.5 million pounds by Samsung Recycling Direct program[8]. Samsung Recycling Direct program was carried out completely different from the official collection program by Government. It may show the company's leadership as much as possible in working in private sector to collect E-wastes

4.2. Beneficial use practice of recycling system

Beneficial use practice of E-wastes recycling was mainly carried out by 9 regional recycling centers in Korea as shown in Table 3[2]. Individual E-wastes such as TV, refrigerator, washing machine, and air conditioner were important items from the viewpoint of economics and environments. Valuable materials from E-wastes such as ferrous, aluminum, copper, and tungsten can be recovered during recovery processes.

In Korea, 9 regional recycling centers had unique specific facilities to recycle certain E-wastes such as refrigerator and washing machines[9]. And recycling center in Gyeongbuk region also had recycling facilities for several types of TV, refrigerator, and washing machines. Recycling centers in north of Gyeonggi and western Metropolitan regions had recycling facilities of the several types of TV, air conditions, refrigerator, and washing machines among E-wastes.

However, the recycling of air conditioner and mobile phone was still at the beginning stage in Korea because of the high recycling cost of mobile phones and the lack of a constant supply of waste mobile phones[10]. A lot of waste mobile phone was stored at home because personal information in mobile phone could not be discarded immediately. In the case of air conditioner, it had various components and consists of complex materials including hazardous substances. As shown in Table 3, the recycling rates of air conditioner and mobile phone in 2013 were only 0.8% and 14.4%, respectively. Recycling technologies for air conditioner were still developing because hazardous substance such as refrigerant should be removed before recycling it.

According to RoHS, hazardous substances in electric and electronic equipment are defined by 6 substances such as Cr^{+6}, Cd, Hg, Pb, PBBs, and PBDEs and a major concern of the current recycling processes was related to the emission of hazardous substances to the environment. Information of the potential hazards about the emission of hazardous pollutants from E-waste recycling facilities to workers has yet to be investigated[11].

Over the past few years much effort on beneficial use practice has been made to better manage E-wastes such as TV, refrigerator, washing machine, etc in Korea. As shown in Table 3, hence, the recycling of TVs, audio, and FAX

machine was pretty good shape for the manufactures or the distributors to take extended responsibility for E-wastes and to play a more vital role in addressing this issue. In order to promote the recycling of E-wastes, the manufacturers or distributors shall assist to develop a technology for the recycling of E-wastes, and provide financial and technical support for the development of recycling technology[12]. Also, the manufacturers or distributors shall support to collect E-wastes as much as possible and establish recycling methods and standards for the proper recycling of E-wastes. Since the role of each stakeholder in recycling can be clearly defined, the environmental impact can be minimized, and more than the obligation target of recycling shall be satisfied.

Finally, the comprehensive network system of E-wastes was established to promote the recycling rate. The network system will provide the information of the generation of E-wastes, recycling companies, and recycled products. Through the activation of the network system of E-wastes, the information of supply and demand of waste should be shared between the recycling centers to operate the recycling facilities steadily.

Table 3. Beneficial use practice of individual E-wastes (2003-2013) (Unit: ton)

Year	2003		2007		2011		2013	
	Amount	Rate	Amount	Rate	Amount	Rate	Amount	Rate
Television	10,360	13.7%	18,977	22.0%	19,585	26.5%	35,294	55.2%
Refrigerator	24,801	12.5%	50,833	19.5%	62,568	27.0%	75,938	34.0%
Washing machine	19,215	31.2%	23,908	24.2%	27,885	28.5%	31,393	31.7%
Air conditioner	846	1.0%	2,907	2.2%	4,060	2.8%	1,178	0.8%
Personal computer	3,154	3.8%	6,103	12.5%	7,141	12.9%	7,764	18.6%
Audio	347	11.4%	404	17.4%	788	19.0%	1,271	49.9%
Mobile phone	515	19.5%	468	16.4%	619	18.7%	411	14.4%
Printer	-	-	2,362	11.1%	2,298	15.7%	3,271	20.7%
Copying machine	-	-	1,150	18.9%	1,002	17.6%	1,633	25.6%
Fax	-	-	171	16.9%	70	19.2%	81	47.4%

*Source: 2014 International Symposium on Recycling of Valuable Resources

5. Summary

Beneficial use practice of recycling E-Waste in Korea were examined to improve recycling activities including collection system, recovery center with facilities by the information of E-Waste generation and recycling, policy and regulations of E-Waste.

Even though total generation of E-wastes was almost constant recently, the generation trend of TV, refrigerator and washing machine was very increased because those products was used in household more than 2 times for past 10 years. Also, recycling rates of those E-wastes will be increased because recycling technologies have been improved and those E-wastes were readily decomposed by heavy parts.

The EPR system and Eco-Assurance System should be managed to improve the recycling rate of wastes efficiently. Since the Allbaro system was traced all business wastes from generation to disposal by submitting the documentation of electronic handover statements, it should be directly monitored in the flow branches with measuring the samples of waste

The establishment of network system for a collection system shall be distributed widely to collect E-wastes such as mobile phone, refrigerator, and air conditioner efficiently. It should be intensified that the mutual aid associations shall be responsible for collection, transportation and recycling by Eco-Assurance System.

Beneficial use practice of recycling E-Waste in Korea can be improved by developing the recycling technologies. Hence, it should make sustained efforts to develop the technologies to recycle E-wastes as secondary resources for recovering materials as well as to procure raw materials.

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